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Plant nutrition science for sustaining public trust

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Introduction

When M. K. Hubbert wrote his Science paper on peak oil in 1949, he noted with concern projections that world population could possibly hit 9 billion within 200 years. The actual increase has been more than twice that fast. And it's projected to continue further. Sustainable intensification of agriculture will be an essential part of our future. Attaining it will require plant nutrition science that sustains public trust.

Industry trends

World cereal production continues to increase, but so does the world human population (Figure 1). While hunger has declined up to 2015, the FAO reports an uptick in the percentage of undernourished people in 2016, and more than 800 million people remain undernourished. The FAO also points out that obesity is on the rise. Thus it is not only the total amount of food produced in terms of calories that is of interest to sustaining human health. The composition, quality and balance of foods produced also matters. The Sustainability Development goals call for zero hunger by 2030, along with improvement in the environment, which implies a strong dependence on sustainable intensification.

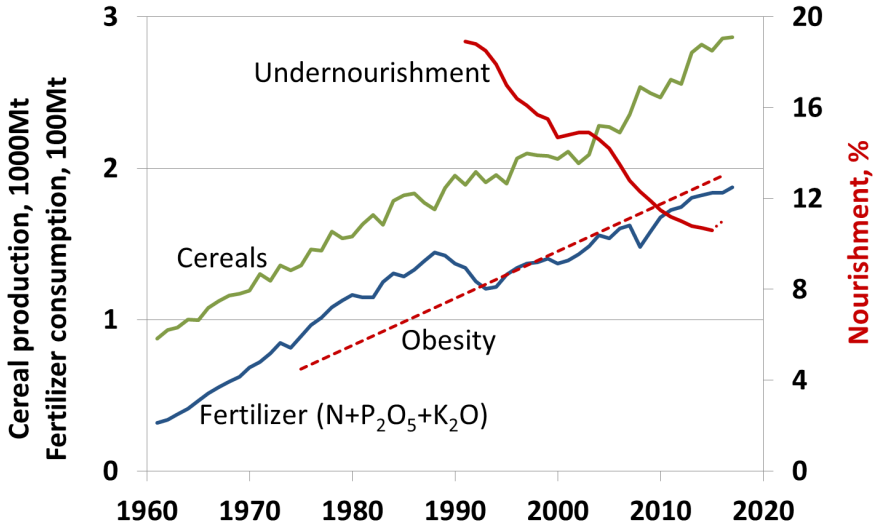

Figure 1. World cereal production and fertilizer consumption, and trends in the proportion of humans malnourished. Data sources: FAO and IFA.

The North American nitrogen industry declined somewhat over the past 20 years but new US production capacity has come on line starting in 2016, with further increases expected (Figure 2). Phosphate and potash fertilizers are produced in surplus to consumption, more so for potash than for phosphate. Potash capacity in North America is expected to increase from 19,554 to 27,589 short tons K2O from 2014 to 2020 (IFDC, 2017), primarily from Canadian mines.

The fertilizer manufacturing industry has seen declining prices since 2012. The Green Markets Weekly U.S. Fertilizer Price Index shows spikes in fertilizer prices in 2008 and 2012. Since 2011-2012, prices have declined, by around 50%, to levels similar to those of 2005-2006. According to the USDA-NASS, the prices paid index for fertilizer declined to around 65% in 2017, relative to the 2011 level. Nevertheless, even adjusted for the consumer price index, US fertilizer prices today are still roughly 75% higher than they were in 2002.

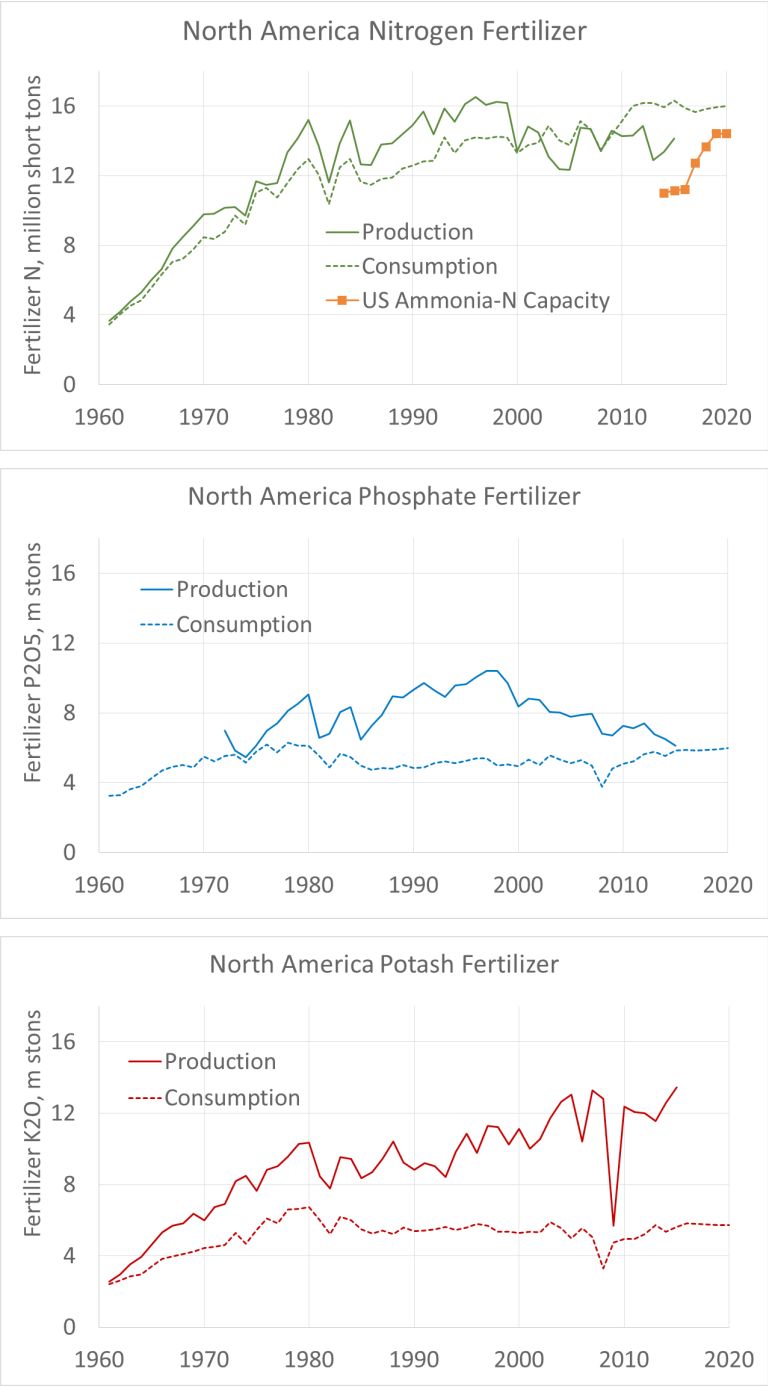

Figure 2. Fertilizer production and consumption in North America, 1961-2015, with consumption and capacity projections to 2020. IFA, 2017; IFDC, 2017; and H. Vroomen, The Fertilizer Institute (TFI).

Challenges for the industry

Sustainability has become a popular word. It is not something easy to define or achieve. But it is one of the goals with which the largest number of people on the planet can agree. Because of its complexity, it is difficult to measure progress toward improving it. Sustainable intensification is tougher than maximum yield – but it's a goal that benefits more people. Measuring and reporting impacts on planet, people and profit is much tougher than helping a grower attain maximum economic yield – but it's a goal the ultimate stakeholders (consumers) can buy into more fully. It's a goal consumers are more likely to appreciate and support through public funding.

Sustainability addresses its three goals simultaneously, rather than attempting solely to address an increasing burden of environmental goals while remaining profitable. Sustainability requires engagement with stakeholders, as well as engagement with experts. Maximum yield and maximum economic yields generally require input from agronomic scientists, producers and crop input retailers. But sustainability goes further, assessing how much issues like clean water, clean air, and climate forcing matter to the people who buy the food, fuel and fiber produced by agriculture. It addresses all the ecosystem services touched by agriculture.

The Millennium Ecosystem Assessment was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, its objective was to assess the consequences of ecosystem change for human well-being. The assessment involved the work of more than 1,360 experts worldwide. Their findings are published online in five technical volumes and six synthesis reports. The assessment supports a simple definition of ecosystem services: the benefits people obtain from ecosystems. It divides such services into four components, provisioning, regulating, cultural and supporting. Agriculture is deeply embedded, not only in the provisioning component with the production of food fiber and fuel, but also in the regulating, cultural and supporting components. Nutrient cycling is an important supporting service. The "ecosystem services" concept is likely to be part of the future of sustainable agriculture.

The crop nutrition industry has been developing frameworks and performance indicators for sustainability, in concert with the implementation of 4R Nutrient Stewardship. The crop nutrition industry seeks to better document practices and link them to outcomes. The practices are the 4Rs: the source-rate-time-place nutrient applications that are "right" for improving sustainability. These 4Rs have the most direct impacts on 3 key outcomes on the farm: productivity, soil health (the soil fertility component and more), and nutrient use efficiency. But they also relate strongly to environmental impacts including water quality, air quality and greenhouse gases.

In the following, project activities of the International Plant Nutrition Institute (IPNI) relating to these indicators and metrics will be reviewed.

Sustainability metrics

Two projects have been initiated to relate 4R practices for specific North American cropping systems to metrics being developed by sustainability organizations. Issue reviews have been developed for both nitrogen and phosphorus practices, working in conjunction with Field to Market, the Alliance for Sustainable Agriculture. These issues reviews are available at http://www.ipni.net/issuereview. Working with sustainability organizations helps deliver messages of the benefits of improved crop nutrition to a wider public audience through the food supply chain.

Data stewardship

The vision for evidence-based nutrient management is to use rigorous, objective, and transparent methods for gathering data from the body of scientific studies and drawing unbiased conclusions about the effectiveness of a given management practice. Agriculture as a discipline is increasingly interested in evidence-based approaches, but many other disciplines–like medicine, human nutrition, and ecology–have already moved into this space, raising the bar for what users of information expect from providers

of information. In October 2017, Dr. T. Scott Murrell and this author presented "The Fertilizer Industry and Importance of Nutrient Management Databases" at the annual meetings of the American Society of Agronomy, Soil Science, and Crop Science in a special symposium entitled, "The Nutrient Uptake and Outcome Network (NUOnet)." IPNI is actively researching the next generation of data synthesis, termed "systematic reviews–the new standard for evidence-based approaches. IPNI is currently gathering information and acquiring technical skills to position itself to conduct its first systematic review to ensure it continues to provide the highest standard of objective information to or on behalf of its members.

Soil test summaries

The soil test summaries, done periodically since 1968 in the days of the Potash & Phosphate Institute, have become much more systematic since 2001, and are being extended to other countries. The numbers of soil tests done annually continue to rise. Figure 3 shows IPNI's soil test phosphorus summary for 12 states of the mid-west centered on Iowa, and including Kentucky, Ohio and Ontario. In this region, as in many others, soil test P varies widely. Despite decades of fertilizer recommendations that, if followed, should tend to converge the values into the optimum range, there is little evidence of that happening. Instead, there is a trend over the past 15 years for the percentage of soils below critical to be increasing, and only small decreases in the percentage of soils testing well above optimum. There is opportunity for improvement.

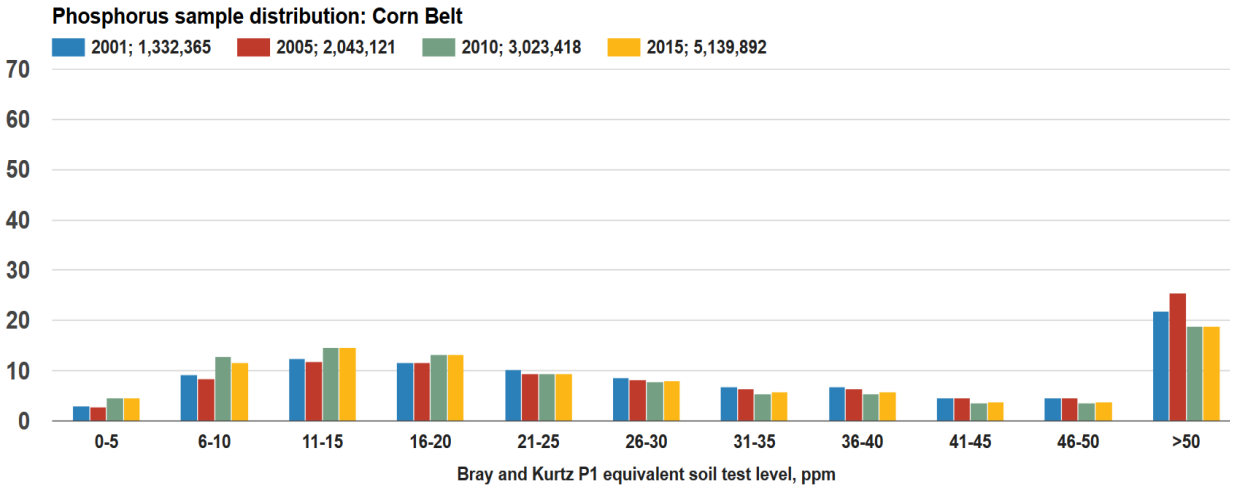

Figure 3. Soil test summary for the Corn Belt states centered around Iowa. http://soiltest.ipni.net/

NuGIS

What started as a map to show nutrient imbalance has become an important tool for research in the environmental sciences. Many components of nutrient flow analysis are poorly known. NuGIS has become a source of data for studies of watershed nutrient flows, cited in high profile geoscience and environmental quality journals. Both NuGIS and the soil test summary show at a large aggregated level the same information accessible to the individual producer for every farm and field. The value of such scalable metrics lies in their ability to be used as benchmarks for individual producers to compare themselves to the rest of their industry.

There are those who would seek to emphasize a single measure. For example, nitrogen balance, the difference between the amount of nitrogen applied to a field and that removed by harvest. For grain corn, it's often a surplus. More is applied than removed. The reverse is true for soybeans. It's true nitrogen balance relates to yield and rate of application. It's true it relates to potential losses, especially when surpluses are large. It can even indicate the mining of soil nutrients and therefore be considered to reflect,

to some degree, soil health. But it still does not stand alone. One can imagine many production decisions leading to a smaller nitrogen surplus that at the same time jeopardize either crop yields or soil health or both. Independent indicators are needed to ensure balance.

Global Maize

The concept of ecological intensification seeks to improve yields while minimizing nutrient losses to conserve land for natural habitat. Using its network across the globe, IPNI established a project comparing farmers' practices with those established by regional teams of experts, aimed at improving both yields and nutrient use efficiency in maize production. The project has gathered a large data set on these measures. Further detail is available at http://research.ipni.net/article/EXP-3006.

Potassium

The Frontiers of Potassium Science Conference, held in Rome, Italy, brought together nearly 130 scientists and agronomists from 37 countries to share key ideas for making much needed changes to potassium soil fertility assessments, fertilization recommendations, and educational efforts. The conference was organized around the Global 4R Nutrient Stewardship Framework: applying the right potassium source, at the right rate, at the right time, and in the right place. Further regional conferences are planned, the first of which took place in India in August 2017. A new book is also forthcoming.

The 4R Research Fund

Presenting research needs and knowledge gaps as key components of a stewardship strategy has motivated the industry to establish an effective 4R Research Fund, currently in its fourth year. Prospects for a second cycle of 5 years are emerging. A key to its success has been the collaboration among the fertilizer industry associations, with The Fertilizer Institute, Fertilizer Canada and IPNI all playing key roles. Since many of the crop nutrition industry's performance indicators are impacted by crop and soil management practices beyond crop nutrition, broadening out this collaboration to include producer associations is underway.

Highlighting the impacts of research

IPNI in the past year has developed several "Research with Impact" items highlighting the value of past research. Topics from North America include the long-term impact of phosphorus on nitrogen use efficiency and nitrate leaching, from Alan Schlegel's long term research in Kansas. These one-pagers get the "value of research" message out to those who influence research funding decisions; people who often don't have time to read the extensive literature that has come out of any given successful project.

Transitions at the International Plant Nutrition Institute

IPNI promotes and develops scientific information to support responsible management of plant nutrition. Key areas of science relevant to managing the source, rate, time and place of nutrient application relate to key performance areas for sustainability. These include productivity, soil health and nutrient use efficiency, all of which can be measured at the farm level and aggregated for higher level reporting. They also include environmental outcomes such as water quality, air quality and greenhouse gas emissions. Communicating the links of practices to these impact areas has potential to improve public trust in agriculture.

The Institute is developing information on many topic areas related to the 4Rs. Here I'll point out some tools you can use to be part of the strategy to prove our worth to society. Things you can implement with your producers that will make a difference to our actual and perceived impact on the sustainability of agriculture and food production.

The IPNI evolved from the Potash and Phosphate Institute. Like its predecessor, it continues to promote and develop science. In the past, the science aimed to support responsible marketing of fertilizers, particularly phosphorus and potassium, although nitrogen was also critical to that mission. Today, it aims

to support responsible management of plant nutrition, a broader mission extending to a wider range of audiences. Responsible management is essentially the definition of stewardship. Stewardship is an essential concept to sustainability and sustainable development, and forms the unifying theme across IPNI's many regions around the world.

Retirements

Dr. Paul Fixen retired in June 2017. Paul began his career with the Institute in 1989, when it was still the Potash & Phosphate Institute, as a director for the North Central Region of the USA. He leaves the Institute a large legacy of science. Throughout his distinguished career, Paul has emphasized the science of nutrient stewardship and how soil fertility and fertilizer use fit into the overall scheme of crop production systems and the environment. Paul has always been at the forefront of global nutrient management research and education. He has authored over 300 articles related to nutrient management including several book chapters, and has developed and taught popular courses at both undergraduate and graduate levels. Memorable titles from his recent presentations include "The science of stewardship" and "The dubious relationship between phosphorus use efficiency and loss mitigation." He completes his term as past-president of the American Society of Agronomy this fall.

Dr. Cliff Snyder also retired in June 2017, after 22 years with the Institute; the last ten as Nitrogen Program Director. Dr. Snyder coordinated the Institute's dealings with environmental issues related to nitrogen fertilizer use in agriculture on a global scale. Dr. Snyder was appointed to the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) Hypoxia Advisory Panel in 2006. In 2008, he was appointed to the U.S. EPA Farm, Ranch and Rural Communities Advisory Committee. He is also an invited contributor to and reviewer within the USDA, U.S. EPA, Field to Market Sustainability Alliance, and other organizations. He is a member of the Science Advisory Committee of the International Nitrogen Initiative, and an invited member of the United Nations Environment Program (UNEP) Steering Committee addressing global nitrous oxide emissions. His legacy lives on in two recent issue reviews, "Progress in Reducing Nutrient Loss in the Mississippi River Basin" and "Suites of 4R Nitrogen Management Practices for Sustainable Crop Production and Environmental Protection." The latter forms the basis for quantifying the nitrous oxide emissions component of Field to Market's greenhouse gas metric.

New scientific staff

Dr. Tai McClellan Maaz has been appointed as Nitrogen Program Director with IPNI effective September 1, 2017. Dr. Maaz will be based from IPNI Headquarters in Peachtree Corners, Georgia. Dr. Maaz's recent post-doctoral fellowship and concurrent research has been focused on the management of nitrogen to minimize losses and improve use within cereal-based agronomic systems including the dryland winter wheat grown in the Palouse region of the Pacific Northwest. Dr. Maaz's Ph.D. research led to recommended economic optimal nitrogen rates for canola in Eastern Washington. She also examined the impact of nitrogen supply, available water, and rotational effects on nitrogen use efficiency. As a Ph.D. student, she received training in the National Science Foundation Integrated Graduate Education Research Training in Nitrogen Systems Policy-oriented Integrated Research and Education (NSPIRE) program. Tai received her Ph.D. from Washington State University (Soil Science) in 2014, and her M.Sc. from the University of Hawaii at Manoa-Tropical Plant and Soil Sciences in 2010. She presently belongs to the Soil Science Society of America, the American Society of Agronomy, as well as the Center for Environmental Research, Education and Outreach at Washington State University.

Dr. Heidi M. Peterson has been hired as Phosphorus Program Director effective September 5, 2017. Dr. Peterson is filling the directorship previously held by Dr. Tom Bruulsema, who was appointed as IPNI Vice President, Americas and Research, earlier this year. Dr. Peterson completed her Ph.D. in Biosystems and Agricultural Engineering (2011) at the University of Minnesota in St. Paul. Her Dissertation was titled "Estimating Renewable Water Flux from Landscape Features." She has a M.Sc. in Agronomy (2003) from Purdue University in West Lafayette, Indiana. Most recently and since 2013, Dr. Peterson worked

as a Research Scientist for the Minnesota Department of Agriculture. She was the lead technical expert on agricultural best management practices (BMPs) needed to address impaired waters issues within the state's agricultural landscapes. The position gave her oversight over research focusing on cover crop establishment and nutrient crediting, precision conservation, nutrient management, and innovative sub-surface drainage treatment. Dr. Peterson has also been actively collaborating with phosphorus research scientists participating within tasked working groups of the Phosphorus Sustainability Research Coordination Network (P-RCN), centered at Arizona State University. Dr. Peterson has been Adjunct Assistant Professor for the Department of Bioproducts & Biosystems Engineering at the University of Minnesota (U of M) since 2014. Previous to these positions, Heidi worked as a Post-Doctoral Research Fellow with the U of M Department of Bioproducts and Biosystems Engineering.

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